

MULTIMEDIA



UNIVERSITY

STUDENT ID NO

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MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2017/2018

EPM2036 – CONTROL THEORY
(TE/RE)

17 MARCH 2018
9.00 a.m. - 11.00 a.m.
(2 Hours)

INSTRUCTIONS TO STUDENT

1. This Question paper consists of 6 pages including cover page with 4 Questions only.
2. Attempt **ALL** questions. All questions carry equal marks and the distribution of the marks for each question is given.
3. Please write all your answers in the answer booklet provided.

Question 1

- (a) A control system is represented by the block diagram shown in Figure Q1a, where $Y(s)$ is the output and $X(s)$ is the input respectively.

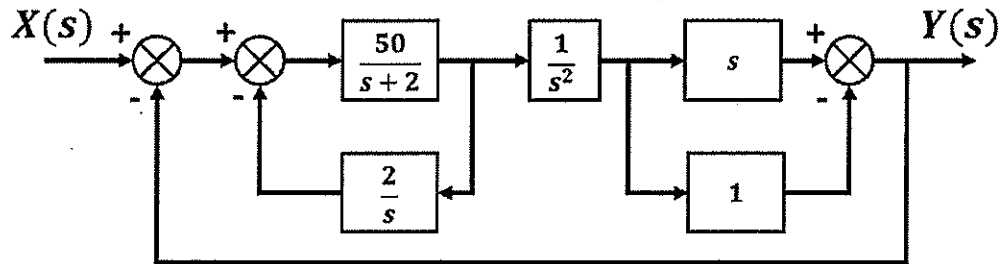


Figure Q1a

- (i) By applying block diagram reduction techniques, determine the transfer function $G(s) = \frac{Y(s)}{X(s)}$. [11 marks]
- (ii) Construct the Signal Flow Graph (SFG) from the block diagram shown in Figure Q1a. [4 marks]
- (b) Determine transfer functions $\frac{X_1(s)}{F_a(s)}$ and $\frac{X_2(s)}{F_a(s)}$ of the translational mechanical system shown in Figure Q1b. K is the spring constant, x_1 and x_2 represent displacements, M_a and M_b denote mass, B_a and B_b denote coefficients of friction, and f_a represents applied force. Assume zero initial conditions.

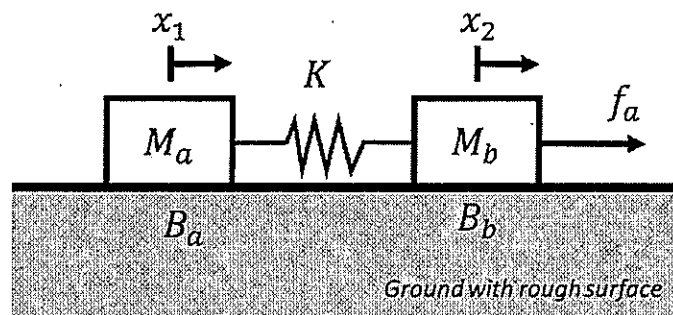


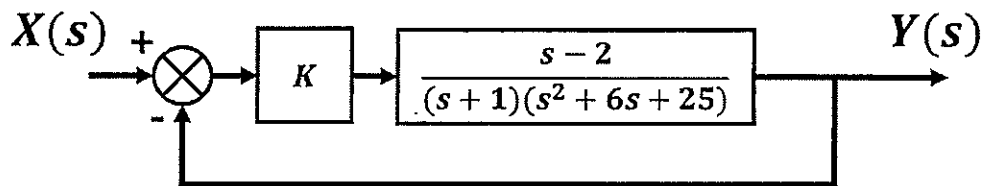
Figure Q1b

[10 marks]

Continued...

Question 2

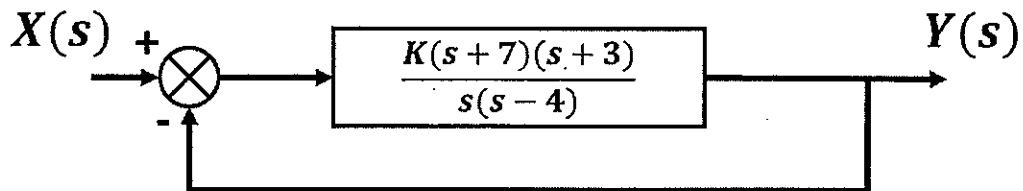
- (a) Consider the open-loop transfer function of a unity feedback system $G(s) = \frac{1}{s(s+1)}$ fed with unit step input, determine
- i) Natural frequency (ω_n) [2 marks]
 - ii) Damping ratio (ξ) [2 marks]
 - iii) Rise time (t_r) [2 marks]
 - iv) Peak time (t_p) [2 marks]
 - v) Settling time (t_s) [2 marks]
 - vi) Maximum overshoot (M_p) [2 marks]
- (b) Consider a negative unity feedback system shown in Figure Q2b, determine the range of K for stability using Routh-Hurwitz criterion.

**Figure Q2b**

[13 marks]

Question 3

- (a) Figure Q3a shows a negative unity feedback control system.

**Figure Q3a**

Construct and label the root locus of the system. [All eight steps of root locus construction analysis must be shown. Justify your answer if particular step is not required.]

[15 marks]

Continued...

- (b) Sketch the asymptotic magnitude Bode plot for the following open loop transfer function on the semi log graph paper provided:

$$G(s)H(s) = \frac{1}{(s + 10)(s + 1)}$$

[10 marks]

Question 4

Consider the open-loop system shown in Figure Q4a.

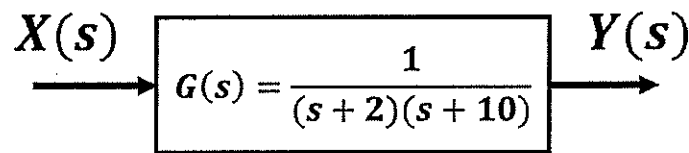


Figure Q4a

- (a) Determine the steady state error if unit step input is fed into the system as shown in Figure Q4a.
- [4 marks]
- (b) Consider the system in Figure Q4a, it is redesigned with Proportional-Integral (PI) controller and negative unity feedback.
- i) Show that how PI controller and negative unity feedback can eliminate the steady state error for a unit step input.
- [5 marks]
- ii) Determine the integral constant, K_I , so that the steady state error due to a unit ramp input is 0.01.
- [6 marks]
- iii) Based on the value of integral constant (K_I from part (ii)), determine the range of possible values for the proportional constant, K_p , so that the closed-loop system is stable.

[10 marks]

End of Paper

Appendix

Laplace Transform Pairs

$f(t)$	$F(s)$
Unit impulse $\delta(t)$	1
Unit step $u(t)$	$\frac{1}{s}$
t	$\frac{1}{s^2}$
$\frac{t^{n-1}}{(n-1)!} \quad (n = 1, 2, 3, \dots)$	$\frac{1}{s^n}$
$t^n \quad (n = 1, 2, 3, \dots)$	$\frac{n!}{s^{n+1}}$
e^{-at}	$\frac{1}{s+a}$
te^{-at}	$\frac{1}{(s+a)^2}$
$\frac{t^{n-1}}{(n-1)!} e^{-at} \quad (n = 1, 2, 3, \dots)$	$\frac{1}{(s+a)^n}$
$t^n e^{-at} \quad (n = 1, 2, 3, \dots)$	$\frac{n!}{(s+a)^{n+1}}$
$\sin \omega t$	$\frac{\omega}{s^2 + \omega^2}$
$\cos \omega t$	$\frac{s}{s^2 + \omega^2}$
$\sinh \omega t$	$\frac{\omega}{s^2 - \omega^2}$
$\cosh \omega t$	$\frac{s}{s^2 - \omega^2}$
$\frac{1}{a}(1 - e^{-at})$	$\frac{1}{s(s+a)}$
$\frac{1}{b-a}(e^{-at} - e^{-bt})$	$\frac{1}{(s+a)(s+b)}$
$\frac{1}{b-a}(be^{-bt} - ae^{-at})$	$\frac{s}{(s+a)(s+b)}$
$\frac{1}{ab} \left[1 + \frac{1}{a-b}(be^{-at} - ae^{-bt}) \right]$	$\frac{1}{s(s+a)(s+b)}$

$\frac{1}{a^2}(1 - e^{-at} - ate^{-at})$	$\frac{1}{s(s+a)^2}$
$\frac{1}{a^2}(at - 1 + e^{-at})$	$\frac{1}{s^2(s+a)}$
$e^{-at} \sin \omega t$	$\frac{\omega}{(s+a)^2 + \omega^2}$
$e^{-at} \cos \omega t$	$\frac{s+a}{(s+a)^2 + \omega^2}$
$\frac{\omega_n}{\sqrt{1-\zeta^2}} e^{-\zeta\omega_n t} \sin \omega_n \sqrt{1-\zeta^2} t$	$\frac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$
$-\frac{1}{\sqrt{1-\zeta^2}} e^{-\zeta\omega_n t} \sin(\omega_n \sqrt{1-\zeta^2} t - \phi)$ $\phi = \tan^{-1} \frac{\sqrt{1-\zeta^2}}{\zeta}$	$\frac{s}{s^2 + 2\zeta\omega_n s + \omega_n^2}$
$1 - \frac{1}{\sqrt{1-\zeta^2}} e^{-\zeta\omega_n t} \sin(\omega_n \sqrt{1-\zeta^2} t + \phi)$ $\phi = \tan^{-1} \frac{\sqrt{1-\zeta^2}}{\zeta}$	$\frac{\omega_n^2}{s(s^2 + 2\zeta\omega_n s + \omega_n^2)}$
$1 - \cos \omega t$	$\frac{\omega^2}{s(s^2 + \omega^2)}$
$\omega t - \sin \omega t$	$\frac{\omega^3}{s^2(s^2 + \omega^2)}$
$\sin \omega t - \omega t \cos \omega t$	$\frac{2\omega^3}{(s^2 + \omega^2)^2}$
$\frac{1}{2\omega} t \sin \omega t$	$\frac{s}{(s^2 + \omega^2)^2}$
$t \cos \omega t$	$\frac{s^2 - \omega^2}{(s^2 + \omega^2)^2}$
$\frac{1}{\omega_2^2 - \omega_1^2} (\cos \omega_1 t - \cos \omega_2 t) (\omega_1^2 \neq \omega_2^2)$	$\frac{s}{(s^2 + \omega_1^2)(s^2 + \omega_2^2)}$
$\frac{1}{2\omega} (\sin \omega t + \omega t \cos \omega t)$	$\frac{s^2}{(s^2 + \omega^2)^2}$